PREDICTION OF URBAN CASUALTIES AND THE MEDICAL LOAD FROM A HIGH-YIELD NUCLEAR BURST

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Albuquerque, New Mexico 87106
II. CASUALTY CURVES FOR PERSONS IN OR SHIELDED BY STRUCTURES

A. DEVELOPMENT OF "BLAST" MORTALITY CURVES FROM JAPANESE AND TEXAS CITY DATA

A great deal of new information has been gathered concerning the biological effects of the nuclear attacks on Hiroshima and Nagasaki, Japan, during World War II. The data from over 35,000 case histories were collected on magnetic tape, and the results of the analysis were published in DC-FR-1054 (Ref. 3).

The Japanese mortality curves for people in or shielded by structures are plotted as a function of overpressure in Figs. 1 and 2 for Hiroshima and Nagasaki, respectively. These curves are based on a yield for Hiroshima of 12.5 kt burst at a height of 1870 feet (scaled height of 806 feet) and a yield for Nagasaki of 22 kt burst at a height of 1640 feet (scaled height of 585 feet).

The mortality curves from the Texas City disaster of 1947, separated by shielding category, are given as a function of overpressure in Fig. 3. This surface burst* has been estimated to be equivalent to a nuclear yield of 0.67 kt.

The next step was to develop a set of "blast" mortality curves for a reference 12.5-kt surface burst. Of course, the ultimate goal was

* Ammonium-nitrate fertilizer exploded within the hold of a ship which was tied up at a pier.
TOTAL MORTALITY CURVES FOR HIROSHIMA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SHIELDING CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRC</td>
<td>SEISMIC REINFORCED CONCRETE</td>
</tr>
<tr>
<td>SRC-B</td>
<td>SEISMIC REINFORCED CONCRETE-BASEMENTS</td>
</tr>
<tr>
<td>SRC-M</td>
<td>SEISMIC REINFORCED CONCRETE-MIDDLE FLOORS</td>
</tr>
<tr>
<td>NRC</td>
<td>NONSEISMIC REINFORCED CONCRETE</td>
</tr>
<tr>
<td>LSF</td>
<td>LIGHT STEEL FRAME</td>
</tr>
<tr>
<td>V</td>
<td>VEHICLES (STREET CARS)</td>
</tr>
<tr>
<td>WFC</td>
<td>WOOD FRAME COMMERCIAL</td>
</tr>
<tr>
<td>WFD</td>
<td>WOOD FRAME DWELLING</td>
</tr>
<tr>
<td>OS</td>
<td>OUTSIDE SHIELDED</td>
</tr>
</tbody>
</table>

MORTALITY (percent)

Overpressure (psi)
FIRE MORTALITY CURVES

PERCENT MORTALITY

PEAK POWER DENSITY ($10^6$ Btu/mi$^2$·sec)

"OUTSIDE" CONSTRUCTION

"LIGHT" CONSTRUCTION

"MEDIUM" CONSTRUCTION

("GERMAN CELLARS")

"HEAVY" CONSTRUCTION
condition for development of firestorms. High ambient winds usually cause conflagrations to develop, as noted above.

B. **FIRE MORTALITY CURVES**

Fires in nine German cities were analyzed in detail to provide data for the development of fire mortality curves. Similar procedures were applied to the fires caused by the nuclear detonation over Hiroshima. Earlier work in this area indicated a correlation between the peak power density (maximum rate of energy release per unit area of the fire bed) and the percent fire mortality for the population at hazard within the fire area.* The four general groupings of construction or shielding categories given by the curves in Fig. 30 are the result of investigating this correlation (Refs. 14 through 18). The general groupings and breakdowns by shielding category are given below:

1) **Heavy Construction**
   a) Seismic Reinforced-Concrete Buildings
   b) Nonseismic Reinforced-Concrete Buildings (Basements)

2) **Medium Construction**
   a) Nonseismic Reinforced-Concrete Buildings (Above Ground)
   b) Heavy Steel-Frame Buildings (Basements)†
   c) Light Steel-Frame Buildings (Basements)†
   d) Heavy Brick Wall-Bearing Buildings (Basements)†

---

*For application of an earlier form of these relationships to historical cases, see Ref. 13.
† If basements are unavailable, this mortality curve probably lies midway between those for medium and light construction.
3) Light Construction
   a) Brick Residential Buildings
   b) Wood-Frame Buildings (Basements) *

4) Outside
   a) Outside-Shielded Category
   b) Outside-Unshielded Category

Two restrictions must be placed on the use of these curves. First, because of the nature of the data available for analysis, the minimum burning area which was analyzed was approximately 20 acres. Consequently, these curves should not be applied to population groups situated in fire environments covering less than 20 acres. Secondly, the shelter postures inherent in the basic German data do not correspond directly to any NFSS or structural shielding categories; therefore, significant variation from the values shown could occur. The curves shown in Fig. 30 are therefore "best estimates."

Computation of the peak power densities (in Btu/mi$^2 \cdot$sec) required to apply the fire mortality curves is described in DC-1FR-1060 (Ref. 4).

C. FIRE INJURIES

This work is still in process, but it is expected that the results will also be presented as a function of the peak power density. The fire injury model will be applied at this point, in parallel with the fire mortality

*If basements are unavailable, this mortality curve probably lies midway between those for light construction and the outside category.
LIST OF REFERENCES


LIST OF REFERENCES (Continued)


15. R. Schubert, Examination of Building Density and Fire Loading in the Districts Eimsbuettel and Hammerbrook of the City of Hamburg in the Year 1943 (20 volumes, in German), Stanford Research Institute; January, 1966.


18. Kathleen F. Earp, Deaths from Fire in Large-Scale Air Attack, with Special Reference to the Hamburg Firestorm, CD/SA 28, Home Office, Scientific Advisers' Branch, London; April, 1953.
Data from Davis, Baker, and Summers, "Analysis of Japanese Nuclear Casualty Data", Reports DC-FR-1045 and 1054, AD653922, AEC and OCD Projects, Dikewood Corp., Albuquerque, N.M.

50% Survival Range, mi

- SRC: Seismic Reinforced Concrete (all) 0.20
- SRC-B: SRC Basement 0.10
- SRC-L: SRC Lower Floors 0.08
- SRC-M: SRC Middle Floors 0.20
- SRC-U: SRC Upper Floors 0.23
- NRC: Non-Seismic Reinforced Concrete 0.32
- LSF: Light Steel Frame 0.46
- OS: Outside, Shielded 0.48
- V: Vehicles 0.48
- WFC: Wood Frame Commercial 0.49
- WFD: Wood Frame Dwelling 0.55
- OU: Outside, Unshielded 0.75

Percentage of Hiroshima survivors as functions of range and exposure conditions.
FLASH BURNS AND IMPACTS (NO "DUCK AND COVER" EVASIVE ACTION)

SOURCE: David I. Feinstein, "Casualty Prediction Comparisons", IIT report AD676183, 1968, 10 Mt surface burst: Figs. 1, 6, 11, 16 and 21, and Table 5

<table>
<thead>
<tr>
<th>Condition</th>
<th>Lethal Peak Overpressure (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoors</td>
<td>3.0</td>
</tr>
<tr>
<td>Wood-House: 2-story</td>
<td>4.2</td>
</tr>
<tr>
<td>Steel-Frame: 6-story</td>
<td>7.3</td>
</tr>
<tr>
<td>Brick House: 3-story</td>
<td>8.4</td>
</tr>
<tr>
<td>Brick House: 7-story</td>
<td>9.2</td>
</tr>
</tbody>
</table>

10 MEGATON SURFACE BURST
MEDIAN LETHAL PEAK OVERPRESSURE
(50% KILLED: STANDING, NO EVASIVE ACTION)*

*Feinstein, AD676183, Table 5 and Figure 21.
ANALYSIS OF JAPANESE NUCLEAR CASUALTY DATA

L. Wayne Davis
William L. Baker
Donald L. Summers

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CAPABILITIES
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CONFIDENTIAL
PHENOMENA AT VARIOUS SCALED BURST HEIGHTS

Figures 5-2A, B, and C show the range from ground zero of various physical phenomena when a burst is on the surface, at a scaled height of 250 $W^{1/3}$ feet, and at a scaled height of 650 $W^{1/3}$ feet, respectively. They are presented primarily for rapid visual comparison of the distance to which the various physical phenomena will extend, and secondarily for a rapid determination of the controlling mechanism of damage at any distance for any yield. From data presented in part one, a similar illustration could be prepared for any scaled or actual burst height.

The significance of the various phenomena curves presented varies with the target being considered. The initial and residual radiation curves are the most significant ones for human targets in the open or in shelters. The values chosen for plotting represent the following:

5 τ—No obvious effect on personnel.

100 τ—Non-lethal dose causing sickness in a few personnel, but permitting a unit to remain operationally effective.

450 τ—Dose lethal within 30 days to 50 percent of personnel exposed.

10,000 τ—Free field dose which will produce a dose of 100 τ for personnel within a shelter having a dose transmission factor of 0.01.

The blast and thermal radiation curves cannot be related directly to damage, because of the increasing duration of blast and thermal phenomena with increasing yield and the dependence of the degree of damage sustained on the duration of the damage-producing effect. To assist in relating the curves presented to expected damage, the following table shows the variation with yield of the magnitude of weapon phenomena required to cause various degrees of damage to certain selected targets. (Refer to secs. VI through XII for a more detailed presentation of damage criteria.)

<table>
<thead>
<tr>
<th>Thermal effects</th>
<th>1 KT</th>
<th>100 KT</th>
<th>10 MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second degree bare skin burn</td>
<td>4</td>
<td>5.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Newspaper ignition</td>
<td>2.9</td>
<td>5.1</td>
<td>9.1</td>
</tr>
<tr>
<td>White pine charring</td>
<td>10</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Air burst damage—Continued</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navy white uniform destruction</td>
<td>34</td>
<td>60</td>
<td>109</td>
</tr>
</tbody>
</table>

Blast effects (in the Mach region):

Severe damage to overpressure sensitive structures:

- Blast-resistant designed buildings (PSI overpressure)...
  - 50
- Reinforced concrete buildings...
  - 10.5
- Monumental wall bearing buildings...
  - 20
- Wood frame housing...
  - 3
- Window pane breakage...
  - 0.5

Severe damage to dynamic pressure sensitive structures:

- Light steel frame single story buildings (PSI dynamic pressure)...
  - 4.5
- Heavy steel frame single story buildings...
  - 6
- Steel frame multistory buildings...
  - 7.5
- 150’-250’ span truss bridges...
  - 50

Some curves are extrapolated beyond data presented in part one, since it is felt that the relationships between phenomena as shown will hold in those regions where there is little supporting knowledge, even though the actual values may be questionable. Since thermal curves are extended beyond one-half the visibility, their interpretation in that region must be approached with caution. In figures B and C, the relative air density would decrease as the actual height of burst is increased in a real case. However, it is held constant for illustrative purposes here. The conversion from slant range to ground range, plus the variation in enhancement of gamma radiation, causes the change in the shape of the radiation curves with change of burst height. Fallout contours are elliptical; only the downwind extent is shown.

Reliability. Varies with the phenomenon of interest. See part one.

Related material.

See paragraph 5.5.
SECTION VI
PERSONNEL CASUALTIES

6.1 Air Blast and Mechanical Injury

a. General. The air blast from a nuclear detonation may cause casualties among human beings in two ways—direct blast injury and indirect blast injury.

b. Direct Blast Injury.

(1) Crushing forces. Although the human body is relatively resistant to the crushing forces which result from air blast loading, large pressure differences resulting from blast wave overpressures may cause damage to lungs, abdominal organs and other gas-filled body organs. Based on data obtained from high explosive detonations, it is estimated that on the order of 200 to 300 psi peak overpressure is required to cause death in humans, provided no translational motion occurs. However, the long duration of the overpressure from a nuclear explosion may appreciably lower this peak overpressure criterion. In any event, no crushing injury other than ear drum rupture occurs for a peak overpressure of less than 35 psi. Although ear drum rupture may result from peak overpressures of 7 to 15 psi, this is not considered a disabling injury, and the overall effectiveness of a unit will not be hampered by the occurrence of these injuries. Therefore, since other damage producing effects are overriding at pressures above 35 psi, crushing forces as such need not be considered as a primary mechanism of producing casualties to personnel in the field.

In structures of certain types, such as bomb shelters or permanent type gun emplacements, where adequate shielding exists against thermal and nuclear radiation, the design of the structure may permit the build-up of blast pressure due to multiple reflections. Blast injuries may therefore occur inside even though the free air overpressure outside the structure would not be sufficient to cause injury.

Both ear drum rupture and other bodily damage which may result from overpressure are largely dependent upon the characteristics of the shock front. If the rise time is long, the body organs are subjected to less severe pressure differences and also are able to better adapt themselves to high overpressure. Consequently, the probability of injury is reduced.

(2) Translational Forces.

(a) Mechanisms. The translational force to which an individual exposed to a blast wave is subjected depends primarily on drag forces. Since the human body is relatively small and the blast wave almost immediately envelopes it, the diffraction process is short. The translational force may be predicted with reasonable accuracy if the burst position, yield, terrain, and the orientation of the human body are known. Since the translational force applied depends on the exposed frontal surface area of the human body, an individual standing in the open is subjected to much larger translational forces than an individual lying on the ground surface. Thus, assuming a prone position at the instant a nuclear bomb flash is detected is quite effective in reducing the likelihood of injuries resulting from bodily translation. In addition, the translational forces are appreciably reduced for an individual
who is behind a building or in a shelter which is sufficiently blast resistant. The degree of protection afforded by a foxhole against injury resulting from translation is not too well known at present. However, appreciable protection should be provided if the foxhole is deep enough to prevent lifting therefrom.

(b) Criteria for injury. Although no direct correlation is known between translational motion parameters and injury, it is reasonable to assume that some relationship exists. The initial rate of acceleration, the motions of various parts of the body while being translated, and the nature of the impact, all certainly contribute to injury. Probably most injuries will result from impact. The severity of injury will depend on the nature of the object or objects with which the translated body collides, the nature of the impact, whether glancing or solid, and the velocity at impact. Some individuals may survive a large translation, whereas others may be severely injured or killed by a relatively small translation. Because increased yield results in increased positive phase duration, attainment of velocities sufficient to cause injury on impact will occur for lower peak pressures. The manner of impact likewise depends on the nature of the terrain and surface configuration. If solid impact occurs, it is estimated that body velocities of about 12 feet per second will produce serious injury approximately 50 percent of the time, while collision at about 17 feet per second will result in approximately 50 percent mortality. Figure 6-1 is a plot of burst height vs. ground range at which 50 percent of standing and prone personnel in the open are expected to become direct blast casualties. The curves are drawn for 1 KT and may be scaled to other yields by multiplying the burst heights by the cube root of the yield and the ground distance by the four-tenths power of the yield.

c. Indirect Blast Injury.

(1) General. Indirect blast casualties result from burial by debris from collapsed structures with attendant production of fractures and crushing injuries, from missiles placed in motion by the blast wave, or from fire or asphyxiation where individuals are prevented from escaping the wreckage.

(2) Personnel in structures. A major cause of personnel casualties in cities is structural collapse and damage. The number of casualties in a given situation may be reasonably estimated if the structural damage is known. Table 6–1 shows estimates of casualty production in two types of buildings for several damage levels. Data from Section VII may be used to predict the ranges at which specified structural damage occurs. Demolition of a brick house is expected to result in approximately 25 percent mortality, with 20 percent serious injury and 10 percent light injury. On the order of 60 percent of the survivors must be extricated by rescue squads. Without rescue they may become fire or asphyxiation casualties, or in some cases be subjected to lethal doses of residual radiation. Reinforced concrete structures, though much more resistant to blast forces, produce almost 100 percent mortality on collapse. The figures of table 6–1 for brick homes are based on data from British World War II experience. It may be assumed that these predictions are reasonably reliable for those cases where the population is in a general state of expectancy of being subjected to bombing and that most personnel have selected the safest places in the buildings as a result of specific air raid warnings. For cases of no prewarning or preparation, the number of casualties is expected to be considerably higher. To make a good estimate of casualty production in structures other
than those listed in table 6-1, it is necessary to consider the type of structural damage that occurs and the characteristics of the resultant missiles. Glass breakage extends to considerably greater ranges than almost any other structural damage, and may be expected to produce large numbers of casualties at ranges where personnel are relatively safe from other effects, particularly for an unwarned population.

Table 6-1. Estimated Casualty Production in Structures for Various Degrees of Structural Damage

<table>
<thead>
<tr>
<th></th>
<th>Killed outright</th>
<th>Serious Injury (hospitalization)</th>
<th>Light Injury (No hospitalization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 story brick homes (high explosive data):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe damage</td>
<td>Percent</td>
<td>Percent</td>
<td>Percent</td>
</tr>
<tr>
<td>Moderate damage</td>
<td>25</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Light damage</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Reinforced-concrete buildings (Japanese data, nuclear):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe damage</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate damage</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Light damage</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>15</td>
</tr>
</tbody>
</table>

Note. These percentages do not include the casualties which may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentage of casualties expected at the maximum range where the specified structural damage occurs. For the distances at which these degrees of damage occur for various yields, see section VII.

6.2 Thermal Injury

a. Introduction. Before attempting to predict the number of thermal casualties which occur in a given situation, it is necessary to recognize the factors which influence the number and distribution of casualties to be expected. These factors include—the distribution or deployment of personnel within the target area, whether proceeding along a road, in foxholes, standing or prone, in the open or under natural cover; orientation with respect to the bomb; clothing, including number of layers, color, weight, and whether the uniform includes helmets, gloves, or other devices which might protect the bare skin, such as flash creas, and natural shielding. These parameters which define the target must be considered along with the factors which define the source of radiation such as yield of the weapon, height of burst, and visibility, as discussed in section III. In many target complexes, a large percentage of thermal casualties may be due to secondary burns. This is particularly true in cities and industrial areas where a major part of the direct radiation may be shielded by intervening structures. Because of the number of factors involved, it is necessary to analyze each particular target situation in order to make realistic predictions of the thermal casualties to be expected.
b. Primary Radiant Energy Burns. Damage to bare skin through the production of burns may be directly related to the radiant exposure and the rate of delivery of the thermal radiation, both of which are yield dependent. For a given total exposure, as the weapon yield increases, the thermal radiation is delivered over a longer period of time and thus at a lower rate. This allows energy loss from the skin surface by conduction to the deeper layers of the skin and by convection to the air. Thus, a given level of damage also is yield dependent. Critical radiant exposures for the production of two degrees of burn on bare skin as a function of yield are presented in figure 6-2 for normal incidence of radiation. Although the data are presented as a single curve, it must be recognized that there will be variations due to factors such as skin color (i.e., darker skin requires a lesser exposure to produce a given severity of burn) and skin temperature (i.e., colder skin as is found in winter or in arctic climates requires a greater exposure to produce the given burn). The curves represent those radiant exposures which will burn 50 percent of any group, including these variants. A first degree burn is defined as one which shows redness; a second degree burn exhibits partial skin destruction or blistering.

c. Burns Under Clothing. Clothing reflects and absorbs much of the thermal radiation incident upon it and thereby protects the wearer against flashburn. In some cases, the protection is complete, but in many cases it is partial in that clothing merely reduces the severity of injury rather than preventing it. At large radiant exposures, there is the additional possibility that the glowing or ignition of the clothing could deliver additional energy to the skin, thereby causing a more severe injury than bare skin would have suffered. There are many factors which contribute to the degree of protection which clothing affords the underlying skin. The thermal resistance of the clothing material itself is probably the most important, as skin burns under undamaged cloth are rarely seen unless the cloth is in close contact with the skin. Other factors are the weight and weave of the fabric; the number of clothing layers worn; the spacing between layers and between the inner layer and the skin; the moisture content, initial temperature, and color of the cloth; the amount and kind of dirt in the cloth; the wind velocity and direction across the surface of the cloth; etc.

The complexity of the interrelations among the above factors makes an accurate prediction extremely difficult. Table 6-2 lists various estimates of radiant exposures required to effect burns under clothing. These values are considered representative of some field conditions, within the limitations due to the varying factors described above.

Table 6-2. Critical Radiant Exposures for Burns Under Clothing
(Expressed in cal/cm² incident on outer surface of cloth)

<table>
<thead>
<tr>
<th>Clothing</th>
<th>1°</th>
<th>2°</th>
<th>100 KT</th>
<th>10 MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer Uniform</td>
<td>8</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>(2 layers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter Uniform</td>
<td>20</td>
<td>25</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>(4 layers)</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>90</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

Note: These values are sensitively dependent upon many variables which are not easily defined (see text), and are probably correct within a factor of two.

d. The Combat Ineffective. A useful term in the discussion of effects of thermal radiation on personnel is "the combat ineffective." A combat ineffective is defined as a person who, because of his injuries, is no longer capable of carrying out his assigned tasks. This is differentiated from the more common term "casualty," which is defined as an individual whose injuries require medical attention. Damage to certain areas of the body produces a greater number of combat ineffectives than damage to other areas. Burns in the area surrounding the eyes which eventually cause the eyes to swell shut, and burns to the hands which lead to loss of mobility are particularly apt to cause ineffectiveness.

If a sufficient portion of the total body area is burned, physiological shock follows and the individual becomes a casualty. When more than 10 to 15 percent of the total body area receives second degree burns or worse, shock may be expected. The efficacy of injuries to the hands and eyes in producing combat ineffectives, coupled with the vulnerability of these parts due to lack of protection under ordinary circumstances, indicates the importance of providing protection for these areas when nuclear attack is likely. Table 6-3 presents estimates of the production of combat ineffectives by various degrees of thermal injury.
<table>
<thead>
<tr>
<th>Geometry</th>
<th>Gamma rays</th>
<th>Neutrons *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Residual</td>
</tr>
<tr>
<td>Foxholes</td>
<td>0.05-0.10</td>
<td>0.02-0.10</td>
</tr>
<tr>
<td>Underground—3 feet</td>
<td>0.04-0.05</td>
<td>0.0002</td>
</tr>
<tr>
<td>Built-up city area (in open)</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>Frame house</td>
<td>0.9</td>
<td>0.3-0.6</td>
</tr>
<tr>
<td>Basement</td>
<td>0.05-0.5</td>
<td>0.05-0.10</td>
</tr>
<tr>
<td>Multistory building:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>0.9</td>
<td>0.01</td>
</tr>
<tr>
<td>Lower</td>
<td>0.3-0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Blockhouse walls:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 inches</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>12 inches</td>
<td>0.05-0.09</td>
<td>0.01-0.02</td>
</tr>
<tr>
<td>24 inches</td>
<td>0.01-0.03</td>
<td>0.001-0.002</td>
</tr>
<tr>
<td>Factory, 200 x 200 feet</td>
<td></td>
<td>0.10-0.20</td>
</tr>
<tr>
<td>Shelter, partly above grade:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With earth cover—2 feet</td>
<td>0.02-0.04</td>
<td>0.003-0.02</td>
</tr>
<tr>
<td>With earth cover—3 feet</td>
<td>0.01-0.02</td>
<td>0.001-0.005</td>
</tr>
</tbody>
</table>

LVT (Landing Vehicle Tracked)            | 0.5-0.9             | 1.0                 |

Battleships and large carriers #:        |                     |                     |
| 15% of crew                            | 1.0                 | 1.0                 | 0.8-1.0              |
| 25% of crew                            | 0.2                 | 0.1                 | 0.2-0.5              |
| 10% of crew                            | 0.05                | 0.03                | 0.05-0.2             |
| 50% of crew                            | 0.0005-0.005        | 0.0003-0.003        | 0.001-0.005          |

Cruisers and carriers #:                |                     |                     |
| 10% of crew                            | 1.0                 | 1.0                 | 0.8-1.0              |
| 20% of crew                            | 0.5                 | 0.3                 | 0.4-0.5              |
| 30% of crew                            | 0.1-0.3             | 0.1                 | 0.1-0.4              |
| 40% of crew                            | 0.005-0.1           | 0.003-0.05          | 0.01-0.1             |

Aircraft:                               | 1.0                 | 1.0                 |

Destroyers, transports, and escort carriers #: |                     |                     |
| 10% of crew                            | 1.0                 | 1.0                 | 0.8-1.0              |
| 20% of crew                            | 0.7                 | 0.5                 | 0.6-0.5              |
| 30% of crew                            | 0.4                 | 0.2                 | 0.3-0.6              |
| 40% of crew                            | 0.1-0.4             | 0.1                 | 0.1-0.3              |

* Estimated values.
* No line-of-sight radiation received.
* Crew at General Quarters.